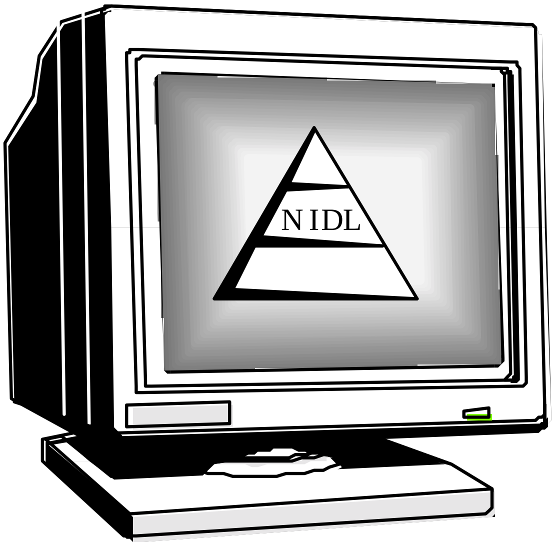

The Orwin Associates 1988 Monochrome CRT Monitor is an excellent 1408 x 1408 pixel, 23 inch monochrome gray scale monitor. The monitor easily passes all the IEC monochrome monitor specifications for both monoscopic and stereo viewing. We have separated the monoscopic from the stereoscopic viewing for grading, but both modes receive an "A" for performance for the Image Analyst and Cartographer applications. This COTS monitor is an excellent display for NIMA Imagery Exploitation Workstations. Accordingly, NIDL certifies the Orwin Associates 1988 Monochrome CRT Monitor as being suitable for IEC workstations requiring a monochrome monitor. The monitor passes all stereo specifications with a Nuvision panel and its associated passive glasses, or with StereoGraphics wired active glasses. We calculated the dynamic range for various amounts of light falling on the face of the tube for monoscopic operation based on our measurements of reflectivity. Thus, we would expect the Orwin 1988 monitor to have a dynamic range of 346:1 with 3 fc and 138:1 for 10 fc falling on the screen. The amount of light falling on the screen can be minimized by using a shield to block strong overhead light to thereby increase the contrast ratio.

Evaluation of the Orwin 1988 Square Aspect Ratio, 20-Inch Diagonal Monochrome Monitor

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C. Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

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NIDL IEC Monitor Certification Report

The Orwin 1988 Monochrome CRT Monitor

FINAL GRADES
Monoscopic Mode: A
Stereoscopic Mode: A

A=Substantially exceeds IEC Requirements; B= Meets IEC Requirements; C=Nearly meets IEC Requirements; F=Fails to meet IEC Requirements in a substantial way

The Orwin Associates 1988 Monochrome CRT Monitor is an excellent 1408 x 1408 pixel, 23 inch monochrome gray scale monitor. The monitor easily passes all the IEC monochrome monitor specifications for both monoscopic and stereo viewing. We have separated the monoscopic from the stereoscopic viewing for grading, but both modes receive an "A" for performance for the Image Analyst and Cartographer applications. This COTS monitor is an excellent display for NIMA Imagery Exploitation Workstations. Accordingly, NIDL certifies the Orwin Associates 1988 Monochrome CRT Monitor as being suitable for IEC workstations requiring a monochrome monitor. The monitor passes all stereo specifications with a Nuvision panel and its associated passive glasses, or with StereoGraphics wired active glasses. We calculated the dynamic range for various amounts of light falling on the face of the tube for monoscopic operation based on our measurements of reflectivity. Thus, we would expect the Orwin 1988 monitor to have a dynamic range of 346:1 with 3 fc and 138:1 for 10 fc falling on the screen. The amount of light falling on the screen can be minimized by using a shield to block strong overhead light to thereby increase the contrast ratio.

The Orwin Associates 1988 Monochrome CRT Monitor has a very wide possible dynamic range. It easily exceeds the 300:1 dynamic range in monoscopic mode, achieving 120 fL (adjustable to 36 fL if desired) for Lmax and 0.1 fL for Lmin for a dynamic range of over 1000:1. We observed 33 fL through the NuVision screen and passive glasses in the stereo mode. The 32:1 extinction ratio far exceeds the requirement in the IEC specification so stereo performance may be better than experienced with some other monochrome or color displays. The StereoGraphics Zscreen and Active StereoGraphics wired glasses also give a high extinction ratio similar to the NuVision screen. The square aspect ratio and the 20 inch diagonal (viewable) give the analyst a large working area surpassed only by 24-inch wide-screen monitors.

The contrast modulation for the Orwin Associates 1988 Monochrome CRT for 1 pixel on/1 pixel off exceeds the IEC requirement by 30% at 120 fL. The contrast modulation is expected to be even higher at lower luminance settings.

We have viewed the Orwin Associates 1988 Monochrome CRT Monitor that has been chosen for use by image analysts at other government sites serviced by Lockheed-Martin Company, Valley Forge, PA. Performance to date has been excellent. A reliability problem found with an excessively tightened crimp has been repaired and the manufacturing procedure modified.

The reliability of Orwin Associates 1988 monitor is stated by the manufacturer as 25,000 hours MTBF and as >20,000 hours for the CRT cathode.

The manufacturer states that they have over thirty years experience in high resolution displays for military, aerospace and custom geospatial and related satellite imaging. The full digital control architecture provides repeatable long term performance and automatic calibration of black level. On-screen user controls are standard, and the menu format separates user controls from service areas with password protection.

The performance in room ambient is listed in the attached NIDL evaluation data sheet. Light incident on the face of the monitor is reflected to the viewer in the amount governed by the reflectivity of the face of the CRT for monoscopic operation, and by the reflectivity of the LCD stereo panel for stereo operation. We calculated the dynamic range for various amounts of light falling on the face of the tube for monoscopic operation based on our measurements of reflectivity. Thus, we would expect the Orwin 1988 monitor to have a dynamic range of 346:1 with 3 fc and 138:1 for 10 fc falling on the screen. Using a shield to block strong overhead light and thereby increase the contrast ratio can minimize the amount of light falling on the screen.

NIDL has evaluated alternative 1600 x 1200 pixel, landscape COTS monochrome monitors from PIC21si/Siemens model number 21103L (Stereo) and from Orwin Associates, model DEX2101L. Both of these monitors have performance very similar to the Orwin 1988. The Orwin 1988 landscape monitor with the NIDL-designed electron gun in native 1408 x 1408 pixel format is like the Orwin 1974D vertically scanning replacement for the specially manufactured original IDEX monitor. Contrast modulation for the 1988 monitor at 1 pixel on/1 pixel off exceeds either the PIC21si or the Orwin DEX2101L at the 120-170 fL luminance levels, while other performance values are similar to the PIC or DEX2101L. Thus, all three monochrome monitors pass the IEC minimum specifications. The choice may be made on price for the IEC workstation or on preferred features.

The Clinton/Orwin website is http://www.cec-displays.com/index2.htm.
The StereoGraphics stereo shutter web site is at http://www.stereographics.com/.
The NuVision LCD stereo shutter web site is at http://www.nuvision3d.com/

Evaluation Datasheet

Mode	IEC Requirement	Measured Performance	Compliance
MONOSCOPIC			
Addressability	1024 x 1024 min.	1408 x 1408	pass
Dynamic Range	25.4 dB	30.0 dB	pass
Luminance (Lmin)	0.1 fL min. ± 4%	0.12 fL	
Luminance (Lmax)	35 fL ± 4%	120fL	pass
Uniformity (Lmax)	28% max.	11.60%	pass
Halation	3.5% max.	1.50%	pass
Color Temp	Not specified	11692 K	
Reflectance	Not specified	7.6%	
Bit Depth	8-bit± 5 counts	8-bit	pass
Step Response	No visible ringing	Clean	pass
Uniformity (Chromaticity)	0.010 delta u'v' max. ± 0.005 Δ u'v'	0.0033 delta u'v'	pass
Pixel aspect ratio	Square, H = V± 6%	Set to square	pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	19.3 ins.	pass
Cm, Zone A, 7.6 inch dia.	35% min.	67%	pass
Cm, Zone A, 40% area	35% min.	64%	pass
Cm, Zone B	20% min.	57%	pass
Pixel density	72 ppi min.	103 ppi	pass
Straightness	0.5% max ± 0.05 mm	0.52%	pass
Linearity	1.0% max ± 0.05 mm	0.73%	pass
Jitter	2 ± 2 mils max.	1.94 mils	pass
Swim, Drift	5 ± 2 mils max.	2.29 mils	pass
Warm-up time, Lmin to +/- 50%	30 mins. Max ± 0.5 minute	6 mins	pass
Warm-up time, Lmin to +/- 10%	60 mins. Max ± 0.5 minute	49 mins	pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute minimum	Set to 73 Hz	pass
STEREOSCOPIC			
Addressability	1024 x 1024 min.	1024 x 2048 (I)	pass
Lmin	0.1 fL min. ± 4%	0.1 fL	pass
Lmax	30 fL min ± 4%	32.7 fL	pass
Dynamic range	24.77 dB min	25.4 dB	pass
Uniformity (Chromaticity)	0.02 delta u'v' max ± 0.005 Δ u'v'	0.005 delta u'v'	pass
Refresh rate	60 Hz per eye, min	60 Hz, per eye	pass
Extinction Ratio	20:1 min	32.1:1 (n)	pass
AMBIENT LIGHTING			
Dynamic Range 24.5 dB (346:1)	N/A	3 fc	
Dynamic Range 21.4 dB (138:1)	N/A	10 fc	

* denotes Moiré cancellation turned ON
(I) denotes interlaced scanning
(n) denotes Nuvision LCD shutter panel

Section I INTRODUCTION

The National Information Display Laboratory (NIDL) was established in 1990 to bring together technology providers - commercial and academic leaders in advanced display hardware, softcopy information processing tools, and information collaboration and communications techniques - with government users. The Sarnoff Corporation in Princeton, New Jersey, a world research leader in high-definition digital TV, advanced displays, computing and electronics, hosts the NIDL.

The present study evaluates a production unit of the Orwin 1988 monochrome CRT high-resolution display monitor. This report is intended for both technical users, such as system integrators, monitor designers, and monitor evaluators, and non-technical users, such as image analysts, software developers, or other users unfamiliar with detailed monitor technology.

The IEC requirements, procedures and calibrations used in the measurements are detailed in the following:

- *NIDL Publication No. 0201099-091*, *Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC),* August 25, 1999.

Two companion documents that describe how the measurements are made are available from the NIDL and the Defense Technology Information Center at http://www.dtic.mil:

- *NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 1: Monochrome CRT Monitor Performance Draft Version 2.0. (ADA353605)*

- *NIDL Publication No. 171795-037 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 2: Color CRT Monitor Performance Draft Version 2.0. (ADA341357)*

Other procedures are found in a recently approved standard available from the Video Electronics Standards Association (VESA) at http://www.vesa.org:

- *VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998.*
  Publication No. 0201099-091, Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC), August 25, 1999.

The IEC workstation provides the capability to display image and other geospatial data on either monochrome or color monitors, or a combination of both. Either of these monitors may be required to support stereoscopic viewing. Selection and configuration of these monitors will be made in accordance with mission needs for each site. NIMA users will select from monitors included on the NIMA-approved Certified Monitor List compiled by the NIDL. The color and monochrome, monoscopic and stereoscopic, monitor requirements are listed in the Evaluation Datasheet.

I.1 The Orwin 1988 Monochrome CRT Monitor

Manufacturer's Specifications

According to Orwin, the specifications for the Orwin 1988 are listed in Table I.1.

Orwin Associates, Inc. has over thirty years experience in high resolution displays for military, aerospace and custom geospatial and related satellite imaging. The Orwin Associates Model D2300 Series, including the Models 1974D (Portrait) and 1988 (Landscape), is based upon the analog Model 2000 used in custom imaging applications requiring maximum pixel resolution. The D2300 Series brings the proven attributes of its predecessors into the digital world of On-Screen user controls and automatic calibration of black level. The auto black level adjustment is triggered thirty minutes after turn-on to reset the electron optics to the .05 fL black level and to repeat at a software defined interval. The On-Screen user interface provides access to the full menu of control functions and is password protected.

The custom electron optics were designed for NIMA type applications wherein the maximum contrast modulation is achieved by controlling the Gaussian distribution of the pixel down to the 5% point. The new optics provide the ability to run at higher luminance levels of 70 fL and maintain a contrast ratio greater than 350:1 with a 61% panel in 1.5fc ambient. Operation at typical NIMA luminance levels provides a minimum of 50% contrast modulation at 100dpi.

The digital architecture provides a flexible platform to accept alternative pixel formats, making future upgrades a function of software. Adjustments to a new format can be accomplished through either the OSD or the RS-232 port using a PC in terminal emulation mode. The menu driven program is contained in the D2300 micro controller eliminating the need to track software updates by field service personnel.

Table I.1
D2300TechnicalData
Including the Models 1974D (Portrait) and 1988 (Landscape)

CRT Specifications	
Size:	23 inch Diagonal
Screen Size:	14.7 x 19.1 Inches
Active Video:	14 x 14 inches
Deflection Angle:	100 deg Diagonal
Phosphor:	P45
Transmittance:	50% Standard, 33% Optional
Brightness	
Output at peak	100 fL (90%panel)
Optional	70 fL (61%panel)
Black level:	0.05 fL (nominal)
Contrast	
Contrast Ratio w/90%:	>250:1 in 1.5fc
Optional w/61%:	>350:1 in 1.5fc
Video Input	
Input voltage:	0.7V Positive
Termination:	50 or 75 Ohms
Sync Input:	TTL, Separate
Scan Rates/Format(preset)	
MONOSCOPIC	
Active Pixels(P):	1408 x 1408
Horizontal:	115 kHz
Vertical:	70 Hz
STEREOSCOPIC	
Active Pixels(L):	1024 x 1024
Horizontal:	150 kHz
Vertical:	120 Hz
Resolvable Pixels (Screen Average)	
Imagery @cm=25%	5.2 Megapixels
Text @cm=50%	4.0 Megapixels MTF no less than 50%
Input Power Requirements Volts:	85 VAC or 265 VAC (auto-range)
Freq.:	48-62 Hz
Watts:	250
Environment & Operating Conditions:	
Temperature Operating:	10 to +40 deg. C
Storage:	-20 to +60 deg. C
Humidity: Operating:	10 to90% non-condensing
Storage:	0 to 95% non-condensing
Vibration: Operating:	0.25 G Peak, 8mm p-p Max
Non-operating:	1.0 G Peak, 4mm p-p Max
Shock Operating:	5 G's Peak
Non-operating:	30 G's Peak
EMI:	FCC ClassA
User Controls	Power On /Off None, Optional Front Mounted
Service Controls	RS-232 port, microprocessor interface for user controls and service.
Dimensions	22.8 W x 18.2 H x 23.5 D (inches)
Weight	100 lbs. approx.

I.2. Initial Monitor Set Up

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5, p 5.

All measurements will be made with the display commanded through a laboratory grade programmable test pattern generator. The system will be operated in at least a 24 bit mode (as opposed to a lesser or pseudo-color mode) for color and at least 8 bits for monochrome. As a first step, refresh rate should be measured and verified to be at least 72 Hz. The screen should then be commanded to full addressability and Lmin set to 0.1 fL. Lmax should be measured at screen center with color temperature between D65 and D93 allowable and any operator adjustment of gain allowable. If a value >35fL is not achieved (>30 fL for color), addressability should be lowered. For a nominal 1200 by 1600 addressability, addressability should be lowered to 1280 by 1024 or to 1024 by 1024. For a nominal 2048 by 2560 addressability, addressabilities of 1200 x 1600 and 1024 x 1024 can be evaluated if the desired Lmax is not achieved at full addressability.

I.3. Equipment

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 2.0, page 3.

The procedures described in this report should be carried out in a darkened environment such that the stray luminance diffusely reflected by the screen in the absence of electron-beam excitation is less than 0.003 cd/m^2 (1mfL).

Instruments used in these measurements included:

- Quantum Data 8701 400 MHz programmable test pattern signal generator
- Quantum Data 903 250 MHz programmable test pattern signal generator
- Photo Research SpectraScan PR-650 spectroradiometer
- Photo Research SpectraScan PR-704 spectroradiometer
- Minolta LS-100 Photometer
- Minolta CA-100 Colorimeter
- Graseby S370 Illuminance Meter
- Microvision Superspot 100 Display Characterization System which included OM-1 optic module (Two Dimensional photodiode linear array device, projected element size at screen set to 1.3 mils with photopic filter) and Spotseeker 4-Axis Positioner

Stereoscopic-mode measurements were made using the following commercially-available stereo products:

- Nuvision 19-inch LCD shutter with passive polarized eyeglasses.

Section II PHOTOMETRIC MEASUREMENTS

II.1. Dynamic range and Screen Reflectance

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.*

VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 199, Section 308-1.

Full screen white-to-black dynamic range measured in 1408 x 1408 format is 30 dB in a dark room. It decreases to less than 22 dB (the absolute threshold for IEC) in 9 fc diffuse ambient illumination.

Objective: Measure the photometric output (luminance vs. input command level) at Lmax and Lmin in both dark room and illuminated ambient conditions.

Equipment: Photometer, Integrating Hemisphere Light Source or equivalent

Procedure: Luminance at center of screen is measured for input counts of 0 and Max Count. Test targets are full screen (flat fields) where full screen is defined addressability. Set Lmin to 0.1 fL. For color monitors, set color temperature between D_{65} to D_{93}. Measure Lmax.

This procedure applies when intended ambient light level measured at the display is 2fc or less. For conditions of higher ambient light level, Lmin and Lmax should be measured at some nominal intended ambient light level (e.g., 18-20 fc for normal office lighting with no shielding). This requires use of a remote spot photometer following procedures outlined in reference 2, paragraph 308-2. This will at best be only an approximation since specular reflections will not be captured. A Lmin > 0.1 fL may be required to meet grayscale visibility requirements.

According to the VESA directed hemispherical reflectance (DHR) measurement method, total combined reflections due to specular, haze and diffuse components of reflection arising from uniform diffuse illumination are simultaneously quantified as a fraction of the reflectance of a perfect white diffuse reflector using the set up depicted in figure II.1-1. Total reflectance was calculated from measured luminances reflected by the screen (display turned off) when uniformly illuminated by an integrating hemisphere simulated using a polystyrene icebox. Luminance is measured using a spot photometer with 1° measurement field and an illuminance sensor as depicted in Figure II.1-1. The measured values and calculated reflectances are given in Table II.1-1.

Data: Define dynamic range by: DR=10log(Lmax/Lmin)

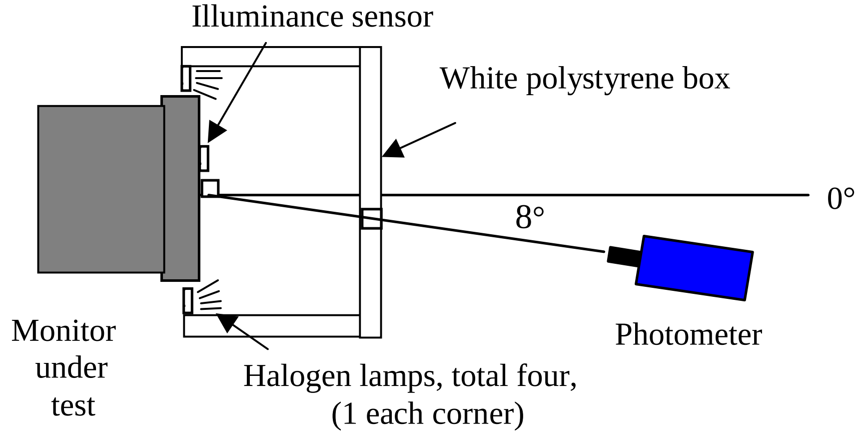


Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

Table II.1-1. Directed Hemispherical Reflectance of Faceplate

VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	25.09 fc
Reflected Luminance	1.91 fL
Faceplate Reflectance	7.6 %

Ambient dynamic ranges of full screen white-to-black given in Table II.1-2 were computed for various levels of diffuse ambient lighting using the measured value for DHR and the darkroom dynamic range measurements. Full screen white-to-black dynamic range decreases from 30 dB in a dark room to 22 dB (the absolute threshold for IEC) in 9 fc diffuse ambient illumination.

Table II.1-2.Dynamic Range in Dark and Illuminated Rooms

Effect of ambient lighting on dynamic range is calculated by multiplying the measured CRT faceplate reflectivity times the ambient illumination measured at the CRT in foot candles added to the minimum screen luminance, Lmin, where Lmin = 0.12 fL.

	Displayed Addressable Format
Ambient Illumination	**1408 x 1408**
0 fc (Dark Room)	30.0 dB
1 fc	27.9 dB
2 fc	26.5 dB
3 fc	25.4 dB
4 fc	24.5 dB
5 fc	23.8 dB
6 fc	23.2 dB
7 fc	22.7 dB
8 fc	22.2 dB
9 fc	21.8 dB
10 fc	21.4 dB

II.2. Maximum Luminance (Lmax)

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.2, p 6.*

The highest luminance for Lmax was 120 fL measured at screen center in 1408 x 1408 format.

Objective: Measure the maximum output display luminance.

Equipment: Photometer

Procedure: See dynamic range. Use the value of Lmax defined for the Dynamic Range measurement.

Data: The maximum output display luminance, Lmax, and associated CIE x, y chromaticity coordinates (CIE 1976) were measured using a hand-held colorimeter (Minolta CA-100).

Table II.2-1. Maximum Luminance and Color

Color and luminance (in fL) for full screen at 100% Lmax taken at screen center.

Format	CCT	CIE x	CIE y	Luminance
1408 x 1408	11692K	0.249	0.312	120fL

II.3. Luminance (Lmax) and Color Uniformity

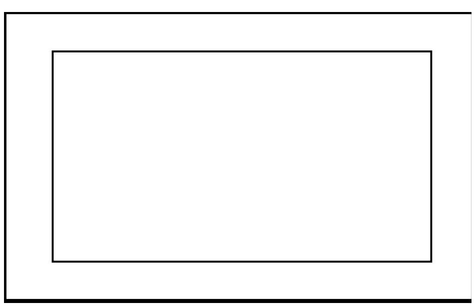
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied by up to 11.6% across the screen. Chromaticity variations were less than 0.004 delta u'v' units.

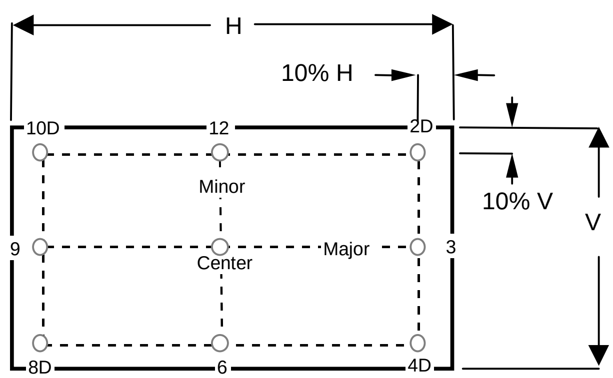
Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

Equipment:
- Video generator
- Photometer
- Spectroradiometer or Colorimeter

Test Pattern: Full screen flat field with visible edges at L_{min} as shown in Figure II.3-1.



Full Screen Flat Field test pattern.
Figure II.3-1



Nine screen test locations.
Figure II.3-2

Procedure: Investigate the temporal variation of luminance and the white point as a function of intensity by displaying a full flat field shown in Figure II.3-1 for video input count levels corresponding L_{max}. Measure the luminance and C.I.E. color coordinates at center screen.

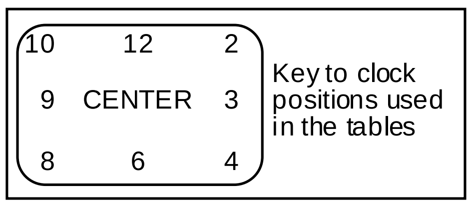
Investigate the temporal variation of luminance and the white point as a function of spatial position by repeating these measurements at each of the locations depicted in Figure II.3-2. Define color uniformity in terms of Δ u´v´.

Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

Table II.3-1.Spatial Uniformity of Luminance and Color
Color and luminance (in fL) for full screen at 100% Lmax taken at nine screen positions.

1408 x 1408

POSITION	CCT	CIE x	CIE y	L, fL
center	11692	0.249	0.312	120
2	11853	0.248	0.311	111
3	11692	0.249	0.312	121
4	11887	0.249	0.309	109
6	11754	0.251	0.308	107
8	11955	0.249	0.308	108
9	11919	0.248	0.310	117
10	11919	0.248	0.310	109
12	11919	0.248	0.310	109



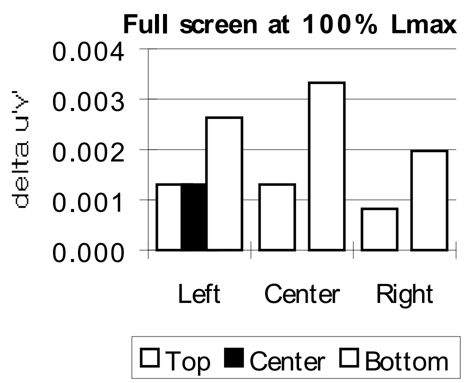


Fig.II.3-3. Spatial Uniformity of Luminance Chromaticity.
(Delta u'v' of 0.004 is just visible.)

II.4. Halation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 4.6, page 48.

Halation was 1.5 % +/- 0.15% on a small black patch surrounded by a large full white area.

Objective: Measure the contribution of halation to contrast degradation. Halation is a phenomenon in which the luminance of a given region of the screen is increased by contributions from surrounding areas caused by light scattering within the phosphor layer and internal reflections inside the glass faceplate. The mechanisms that give rise to halation, and its detailed non-monotonic dependence on the distance along the screen between the source of illumination and the region being measured have been described by E. B. Gindele and S.L. Shaffer. The measurements specified below determine the percentage of light that is piped into the dark areas as a function of the extent of the surrounding light areas.

Equipment:
- Photometer
- Video generator

Test Pattern:

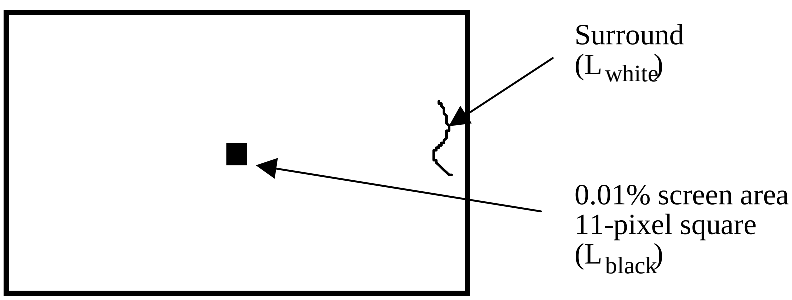


Figure II.4-1 *Test pattern for measuring halation.*

Procedure: Note: The halation measurements require changing the setting of the BRIGHTNESS control and will perturb the values of L_{max} and L_{min} that are established during the initial monitor set-up. The halation measurements should therefore be made either first, before the monitor setup, or last, after all other photometric measurements have been completed.

Determine halation by measuring the luminance of a small square displayed at L_{black} (essentially zero) and at L_{white} when surrounded by a much larger square displayed at L_{white} (approximately 75% L_{max}).

Establish L_{black} by setting the display to cutoff. To set the display to cut-off, display a flat field using video input count level zero, and use a photometer to monitor the luminance at center screen. Vary the BRIGHTNESS control until the CRT beam is visually cut off, and confirm that the corresponding luminance (L_{stray}) is essentially equal to zero. Fine tune the BRIGHTNESS control such that

CRT beam is just on the verge of being cut off. These measurements should be made with a photometer which is sensitive at low light levels (below L_{min} of the display). Make no further adjustments or changes to the BRIGHTNESS control or the photometer measurement field.

Next, decrease the video input level to display a measured full-screen luminance of 75% L_{max} measured at screen center. Record this luminance (L_{white}).

The test target used in the halation measurements is a black (L_{black}) square patch of width equal to 0.01% of the area of addressable screen, the interior square as shown in Figure II.4-1. The interior square patch is enclosed in a white (L_{white}) background encompassing the remaining area of the image. The exterior surround will be displayed at 75% L_{max} using the input count level for L_{white} as determined above. The interior square will be displayed at input digital count level zero.

Care must be taken during the luminance measurement to ensure that the photometer's measurement field is less than one-half the size of the interior square and is accurately positioned not to extend beyond the boundary of the interior square. The photometer should be checked for light scattering or lens flare effects which allow light from the surround to enter the photosensor. A black card with aperture equal to the measurement field (one-half the size of the interior black square) may be used to shield the photometer from the white exterior square while making measurements in the interior black square.

Analysis: Compute the percent halation for each test target configuration. Percent halation is defined as:

$$\% \text{ Halation} = L_{black} \,/\, (L_{white} - L_{black}) \times 100$$

Where, L_{black} = measured luminance of interior square displayed at L_{black} using input count level zero,

L_{white} = measured luminance of interior square displayed at L_{white} using input count level determined to produce a full screen luminance of 75% L_{max} .

Data: Table II.4-1 contains measured values of L_{black}, L_{white} and percentage halation.

Table II.4-1 Halation for 1408 x 1408 Addressability

	Reported Values	Range for 4% uncertainty
Lblack	1.29fL ± 4%	1.24fL to 1.34fL
Lwhite	86.8fL ± 4%	83.3fL to 90.3fL
Halation	1.49% ± 0.12%	1.37% to 1.61%

II.5. Color Temperature

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 5.4, page 22.

The CCT of the measured white point is 11692K and is not specified for monochrome monitors for IEC.

II.6. Bit Depth

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.

Positive increases in luminance were measured for each of the 256 input levels for 8 bits of gray scale. Neither black level clipping nor white level saturation was observed.

Objective: Measure the number of bits of data that can be displayed as a function of the DAC and display software.

Equipment: Photometer

Test targets: Targets are n four inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels.

Procedure: Measure patch center for all patches with Lmin and Lmax as defined previously. Count number of monotonically increasing luminance levels. Use the NEMA/DICOM model to define discriminable luminance differences. For color displays, measure white values.

Data: Define bit depth by $\log_2$ (number of discrete luminance levels)

The number of bits of data that can be displayed as a function of the input signal voltage level were verified through measurements of the luminance of white test targets displayed using a Quantum Data 8701 test pattern generator and a Minolta CA-100 colorimeter. Targets are n four-inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels. The NEMA/DICOM model was used to define discriminable luminance differences in JNDs.

Figure II.6-1 shows the System Tonal Transfer curve at center screen as a function of input counts. The data for each of the 256 levels are listed in Tables II.6-1 and II.6-2.

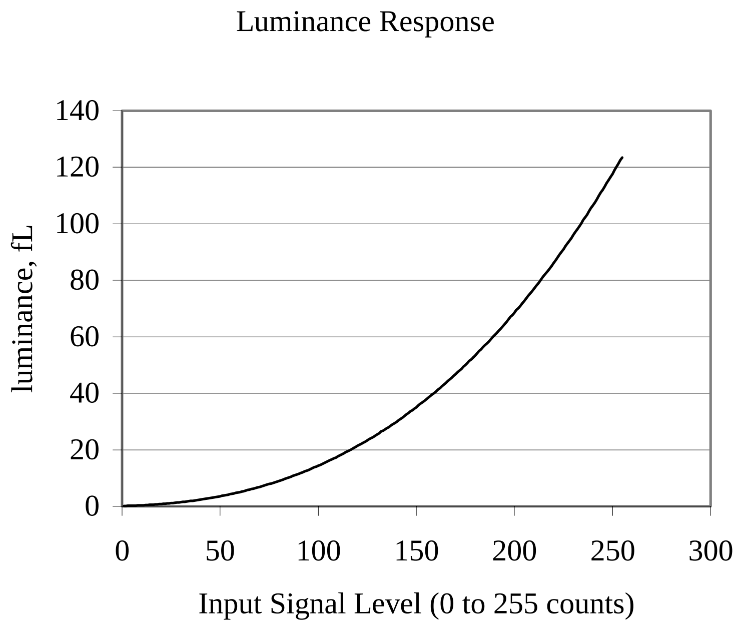


Figure II.6-1. System Tonal Transfer at center screen as a function of input counts.

Table II.6-1. System Tonal Transfer at center screen as a function of input counts. Target levels 000 to 127.

Back Ground	Target	L, fL	Diff, fL	Diff, JND
38	0	0.134	0	0
39	1	0.151	0.017	4
39	2	0.168	0.017	4
39	3	0.188	0.02	3
40	4	0.207	0.019	4
40	5	0.239	0.032	5
41	6	0.25	0.011	2
41	7	0.277	0.027	4
41	8	0.301	0.024	3
42	9	0.33	0.029	4
42	10	0.36	0.03	4
42	11	0.394	0.034	4
43	12	0.448	0.054	6
43	13	0.484	0.036	4
43	14	0.525	0.041	4
44	15	0.567	0.042	4
44	16	0.611	0.044	4
44	17	0.656	0.045	4
45	18	0.711	0.055	4
45	19	0.76	0.049	4
45	20	0.81	0.05	4
46	21	0.867	0.057	4
46	22	0.926	0.059	4
46	23	0.984	0.058	4
47	24	1.044	0.06	4
47	25	1.108	0.064	4
48	26	1.175	0.067	4
48	27	1.247	0.072	4
48	28	1.311	0.064	3
49	29	1.387	0.076	4
49	30	1.467	0.08	4
49	31	1.547	0.08	4
50	32	1.625	0.078	4
50	33	1.693	0.068	3
50	34	1.782	0.089	4
51	35	1.873	0.091	4
51	36	1.962	0.089	3
51	37	2.057	0.095	4
52	38	2.154	0.097	4
52	39	2.257	0.103	3
52	40	2.353	0.096	4
53	41	2.461	0.108	4
53	42	2.578	0.117	4
53	43	2.689	0.111	3
54	44	2.795	0.106	4
54	45	2.913	0.118	3
55	46	3.041	0.128	4
55	47	3.17	0.129	4
55	48	3.295	0.125	3
56	49	3.429	0.134	4
56	50	3.558	0.129	3
56	51	3.692	0.134	4
57	52	3.829	0.137	3
57	53	3.972	0.143	4
57	54	4.124	0.152	3
58	55	4.267	0.143	4
58	56	4.413	0.146	3
58	57	4.568	0.155	3
59	58	4.731	0.163	4
59	59	4.895	0.164	3
59	60	5.043	0.148	3
60	61	5.221	0.178	4
60	62	5.382	0.161	3
60	63	5.548	0.166	3

Back Ground	Target	L, fL	Diff, fL	Diff, JND
61	64	5.762	0.214	4
61	65	5.896	0.134	2
62	66	6.097	0.201	4
62	67	6.272	0.175	3
62	68	6.471	0.199	3
63	69	6.652	0.181	3
63	70	6.856	0.204	3
63	71	7.063	0.207	3
64	72	7.238	0.175	3
64	73	7.457	0.219	3
64	74	7.664	0.207	3
65	75	7.883	0.219	3
65	76	8.091	0.208	3
65	77	8.307	0.216	3
66	78	8.543	0.236	3
66	79	8.762	0.219	3
66	80	8.969	0.207	3
67	81	9.22	0.251	3
67	82	9.457	0.237	3
67	83	9.728	0.271	3
68	84	9.938	0.21	2
68	85	10.18	0.242	3
69	86	10.43	0.25	3
69	87	10.72	0.29	3
69	88	10.94	0.22	3
70	89	11.21	0.27	2
70	90	11.5	0.29	3
70	91	11.74	0.24	3
71	92	12.05	0.31	3
71	93	12.3	0.25	2
71	94	12.59	0.29	3
72	95	12.85	0.26	3
72	96	13.14	0.29	2
72	97	13.46	0.32	3
73	98	13.78	0.32	3
73	99	14.09	0.31	3
73	100	14.36	0.27	2
74	101	14.67	0.31	3
74	102	14.99	0.32	2
74	103	15.32	0.33	3
75	104	15.62	0.3	3
75	105	15.97	0.35	2
76	106	16.29	0.32	3
76	107	16.62	0.33	2
76	108	16.97	0.35	3
77	109	17.28	0.31	2
77	110	17.66	0.38	3
77	111	18.01	0.35	2
78	112	18.36	0.35	3
78	113	18.7	0.34	2
78	114	19.11	0.41	3
79	115	19.47	0.36	2
79	116	19.82	0.35	3
79	117	20.23	0.41	2
80	118	20.63	0.4	3
80	119	20.96	0.33	2
80	120	21.37	0.41	2
81	121	21.75	0.38	3
81	122	22.14	0.39	2
81	123	22.53	0.39	2
82	124	22.92	0.39	2
82	125	23.35	0.43	3
83	126	23.76	0.41	2
83	127	24.13	0.37	2

Table II.6-2. System Tonal Transfer at center screen as a function of input counts Target levels 128 to 255.

Back ground	Target	L, fL	Diff, fL	Diff, JND
83	128	24.52	0.39	2
84	129	24.96	0.44	2
84	130	25.43	0.47	3
84	131	25.9	0.47	2
85	132	26.48	0.58	3
85	133	26.71	0.23	1
85	134	27.21	0.5	3
86	135	27.66	0.45	2
86	136	28.04	0.38	2
86	137	28.54	0.5	2
87	138	29.04	0.5	3
87	139	29.51	0.47	2
87	140	29.97	0.46	2
88	141	30.44	0.47	2
88	142	30.97	0.53	2
88	143	31.43	0.46	2
89	144	31.96	0.53	2
89	145	32.48	0.52	3
90	146	33.04	0.56	2
90	147	33.68	0.64	3
90	148	34.06	0.38	1
91	149	34.62	0.56	2
91	150	35.08	0.46	2
91	151	35.67	0.59	2
92	152	36.22	0.55	3
92	153	36.75	0.53	2
92	154	37.3	0.55	2
93	155	37.85	0.55	2
93	156	38.41	0.56	2
93	157	38.99	0.58	2
94	158	39.52	0.53	2
94	159	40.07	0.55	1
94	160	40.63	0.56	2
95	161	41.27	0.64	3
95	162	41.85	0.58	1
95	163	42.53	0.68	3
96	164	43.08	0.55	1
96	165	43.66	0.58	2
97	166	44.31	0.65	2
97	167	44.92	0.61	2
97	168	45.47	0.55	2
98	169	46.17	0.7	2
98	170	46.79	0.62	2
98	171	47.46	0.67	2
99	172	48.04	0.58	2
99	173	48.68	0.64	2
99	174	49.38	0.7	2
100	175	50.03	0.65	1
100	176	50.64	0.61	2
100	177	51.46	0.82	2
101	178	52.07	0.61	2
101	179	52.76	0.69	2
101	180	53.41	0.65	2
102	181	54.23	0.82	2
102	182	54.96	0.73	2
102	183	55.56	0.6	1
103	184	56.33	0.77	2
103	185	56.97	0.64	2
104	186	57.74	0.77	2
104	187	58.37	0.63	1
104	188	59.14	0.77	2
105	189	59.92	0.78	2
105	190	60.62	0.7	2
105	191	61.38	0.76	1

Back ground	Target	L, fL	Diff, fL	Diff, JND
106	192	62.08	0.7	2
106	193	62.82	0.74	2
106	194	63.69	0.87	2
107	195	64.47	0.78	1
107	196	65.29	0.82	2
107	197	66.24	0.95	2
108	198	67.13	0.89	2
108	199	67.63	0.5	1
108	200	68.47	0.84	2
109	201	69.52	1.05	2
109	202	70.22	0.7	2
109	203	70.95	0.73	1
110	204	71.86	0.91	2
110	205	72.65	0.79	2
111	206	73.58	0.93	2
111	207	74.51	0.93	1
111	208	75.27	0.76	2
112	209	76.12	0.85	1
112	210	77.05	0.93	2
112	211	77.96	0.91	2
113	212	78.83	0.87	2
113	213	79.68	0.85	1
113	214	80.67	0.99	2
114	215	81.58	0.91	1
114	216	82.42	0.84	2
114	217	83.21	0.79	1
115	218	84.2	0.99	2
115	219	85.17	0.97	2
115	220	86.1	0.93	1
116	221	87.09	0.99	2
116	222	88.03	0.94	2
116	223	89.05	1.02	1
117	224	89.98	0.93	2
117	225	91.01	1.03	1
118	226	92.11	1.1	2
118	227	93.05	0.94	2
118	228	93.98	0.93	1
119	229	94.86	0.88	2
119	230	96.02	1.16	1
119	231	97.08	1.06	2
120	232	97.95	0.87	1
120	233	99.06	1.11	2
120	234	100.1	1.04	1
121	235	101.3	1.2	2
121	236	102.3	1	2
121	237	103.2	0.9	1
122	238	104.4	1.2	2
122	239	105.5	1.1	1
122	240	106.5	1	2
123	241	107.6	1.1	1
123	242	108.7	1.1	2
123	243	110	1.3	1
124	244	111.1	1.1	2
124	245	112	0.9	1
125	246	113.1	1.1	1
125	247	114.4	1.3	2
125	248	115.4	1	1
126	249	116.6	1.2	2
126	250	117.7	1.1	1
126	251	119	1.3	2
127	252	120.2	1.2	2
127	253	121.3	1.1	1
127	254	122.5	1.2	1
128	255	123.5	1	2

II.8. Luminance Step Response

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.8, p 7.

No video artifacts were observed.

Objective: Determine the presence of artifacts caused by undershoot or overshoot.

Equipment: Test targets, SMPTE Test Pattern RP-133-1991, 2-D CCD array

Procedure: Display a center box 15% of screen size at input count levels corresponding to 25%, 50%, 75%, and 100% of Lmax with a surround of count level 0. Repeat using SMPTE Test pattern

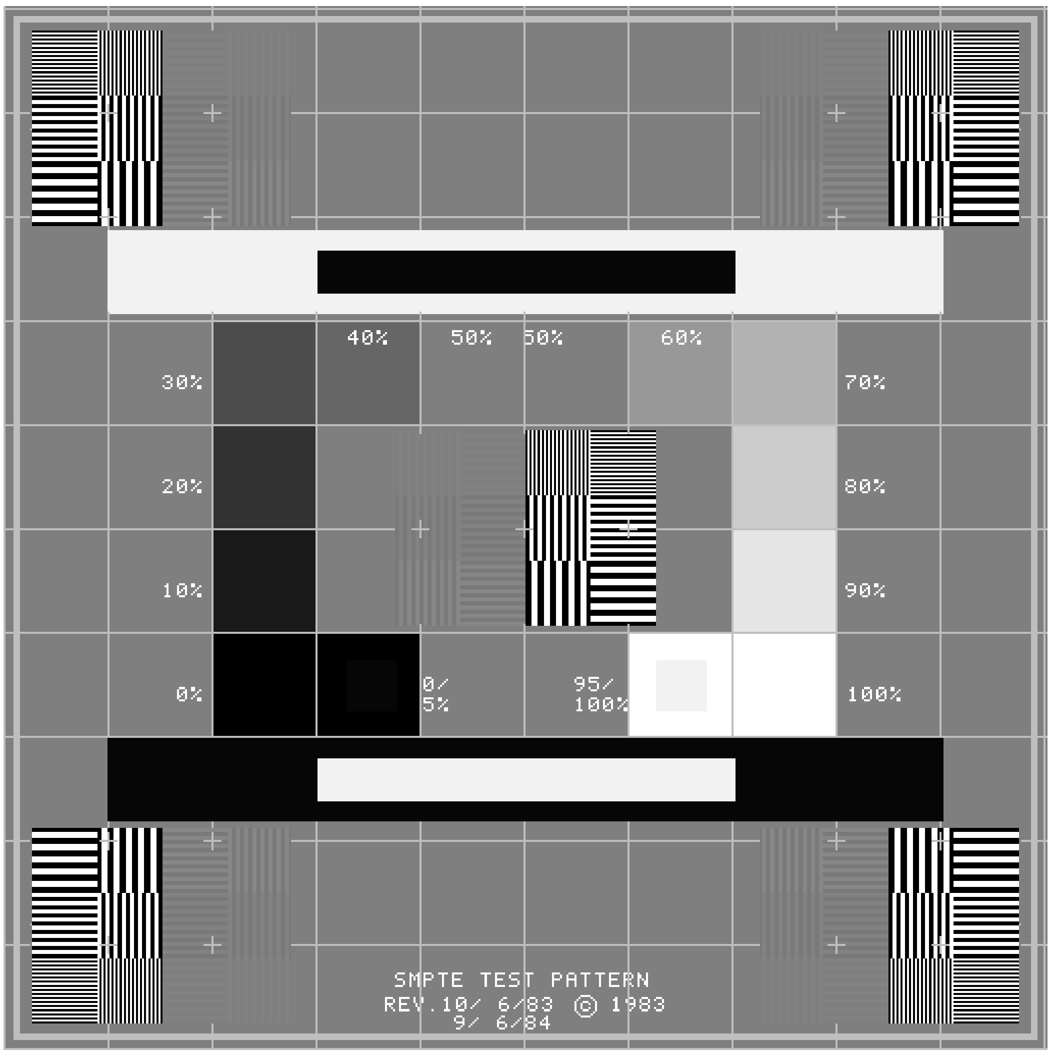


Figure II.8-1. SMPTE Test Pattern .

Data: Define pass by absence of noticeable ringing, undershoot, overshoot, or streaking.

The test pattern shown in Figure II.8-1 was used in the visual evaluation of the monitor. This test pattern is defined in SMPTE Recommended Practice RP-133-1986 published by the Society of Motion Picture and Television Engineers (SMPTE) for medical imaging applications. Referring to the large white-in-black and black-in-white horizontal bars contained in the test pattern, RP133-1986, paragraph 2.7 states " These areas of maximum contrast facilitate detection of mid-band streaking (poor low-frequency response), video amplifier ringing or overshoot, deflection interference, and halo." None of these artifacts was observed in the ORWIN 1988 monitor, signifying good electrical performance of the video circuits.

II.9. Addressability

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1, page 67.

This monitor properly displayed all addressed pixels for the following tested formats (HxV): 1408 x 1408x 72 Hz, and 1024 x 1024 x 120 Hz.

Objective: Define the number of addressable pixels in the horizontal and vertical dimension; confirm that stated number of pixels is displayed.

Equipment: Programmable video signal generator.
Test pattern with pixels lit on first and last addressable rows and columns and on two diagonal lines beginning at upper left and lower right; H & V grill patterns 1-on/1-off.

Procedure: The number of addressed pixels were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible. All perimeter lines were confirmed to be visible, with no irregular jaggies on diagonals and, for monochrome monitors, no strongly visible moiré on grilles.

Data: If tests passed, number of pixels in horizontal and vertical dimension. If test fails, addressability unknown.

Table II.9-1 Addressabilities Tested

Monoscopic Mode	Stereo Mode
1408 x 1408	1024 x 1024

II.10. Pixel Aspect Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.10, p 8.

Pixel aspect ratio is within 0.6%.

Objective: Characterize aspect ratio of pixels.

Equipment: Test target, measuring tape with at least 1/16th inch increments

Procedure: Display box of 400 x 400 pixels at input count corresponding to 50% Lmax and background of 0. Measure horizontal and vertical dimension.

Alternatively, divide number of addressable pixels by the total image size to obtain nominal pixel spacings in horizontal and vertical directions.

Data: Define pass if H= V± 6% for pixel density <100 ppi and ± 10% for pixel density > 100 ppi.

	Monoscopic Mode
Addressability (H x V)	1408 x 1408
H x V Image Size (inches) H x V Pixel Spacing (mils) H x V Pixel Aspect Ratio	13.715 x 13.631 9.74 x 9.68 mils H = V + 0.6%

II.11. Screen Size (Viewable Active Image)

Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

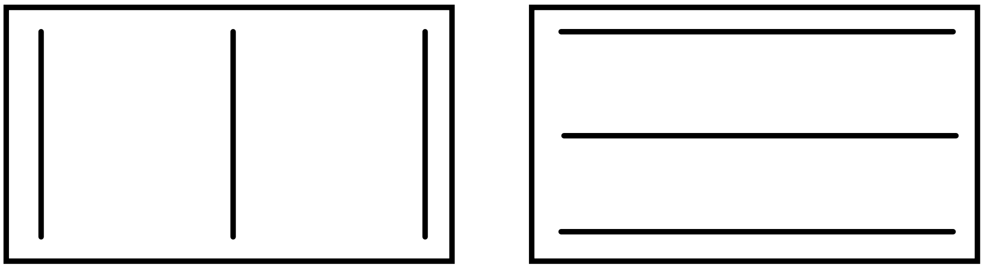
Image size as tested was 19.337 inches in diagonal.

Objective: Measure beam position on the CRT display to quantify width and height of active image size visible by the user (excludes any overscanned portion of an image).

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.11-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be

positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.11-1 Three-line grille test patterns.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates of lines at the ends of the major and minor axes.

Data: Compute the image width defined as the average length of the horizontal lines along the top, bottom and major axis of the screen. Similarly, compute the image height defined as the average length of the vertical lines along the left side, right side, and minor axis of the screen. Compute the diagonal screen size as the square-root of the sum of the squares of the width and height.

Table II.11-1. Image Size

	Monoscopic Mode
Addressability (H x V)	1408 x 1408
H x V Image Size (inches) Diagonal Image Size (inches)	13.715 x 13.631 19.337

II.12. Contrast Modulation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 5.2, page 57.

Contrast modulation (Cm) for 1-on/1-off grille patterns displayed at 50% Lmax exceeded Cm = 64% in Zone A, and exceeded Cm = 57 % in Zone B.

Objective: Quantify contrast modulation as a function of screen position.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Photometer with linearized response

Procedure: The maximum video modulation frequency for the 1408 x 1408 format was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen center and at eight peripheral screen positions. The measurements should be along the horizontal and vertical axes and along the diagonal from these axes. Use edge measurements no more than 10% of screen size in from border of active screen. The input signal level was set so that 1-line-on/1-line-off horizontal grille patterns produced a screen area-luminance of 25% of maximum level, Lmax.

Zone A is defined as a 24 degree subtended angle circle from a viewing distance of 18 inches (7.6 inch circle). Zone B is the remainder of the display. Use edge measurements no more than 10% of screen size in from border of active screen area to define Cm for Zone B (remaining area outside center circle). Determine Cm at eight points on circumference of circle by interpolating between center and display edge measurements to define Cm for Zone A. If measurements exceed the threshold, do not make any more measurements. If one or more measurements fail the threshold, make eight additional measurements at the edge (but wholly within) the defined circle.

Data: Values of vertical and horizontal Cm for Zone A and Zone B are given in Table II.12-1. The contrast modulation, Cm, is reported (the defining equation is given below) for the 1-on/1-off grille patterns. The modulation is equal to or greater than 64% in Zone A, and is equal to or greater than 57% in Zone B.

$$C_m = \frac{L_{peak} - L_{valley}}{L_{peak} + L_{valley}}$$

Table II.12-1. Contrast Modulation
Corrected for lens flare and Zone Interpolation

Zone A 7.6-inch diameter circle for 24-degree subtended angle at 18-inch viewing distance area

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	91%	57%			91%	75%			93%	68%
			93%	68%	93%	75%	94%	72%		
Major	93%	65%	94%	70%	95%	75%	92%	67%	90%	60%
			95%	75%	92%	77%	94%	73%		
Bottom	95%	76%			89%	78%			93%	70%

Zone A 9.76-inch diameter circle for 40% area

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	91%	57%			91%	75%			93%	68%
			93%	66%	92%	75%	94%	72%		
Major	93%	65%	94%	68%	95%	75%	91%	64%	90%	60%
			95%	76%	91%	77%	94%	72%		
Bottom	95%	76%			89%	78%			93%	70%

II.13. Pixel Density

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.13, p 9.

Pixel density was set to 103 ppi for the 1408 x 1408 addressable format.

Objective: Characterize density of image pixels

Equipment: Measuring tape with at least 1/16 inch increments

Procedure: Measure H&V dimension of active image window and divide by vertical and horizontal addressability

Data: Define horizontal and vertical pixel density in terms of pixels per inch

Table II.13-1. Pixel-Density

	Monoscopic Mode
Addressability (H x V)	1408 x 1408
H x V Image Size (inches) H x V Pixel Density, ppi	13.715 x 13.631 103 x 103

II.14. Moiré

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.14, p 9.

Not applicable to monochrome monitors.

II.15. Straightness

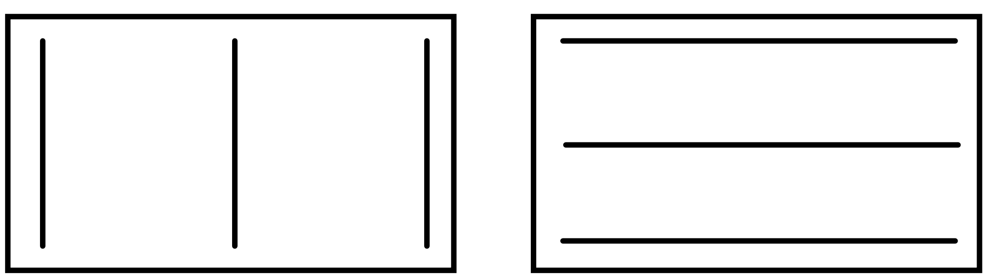
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Waviness, a measure of straightness, did not exceed 0.52% of the image width or height.

Objective: Measure beam position on the CRT display to quantify effects of waviness which causes nonlinearities within small areas of the display distorting nominally straight features in images, characters, and symbols.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.15-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.15-1 Three-line grille test patterns.

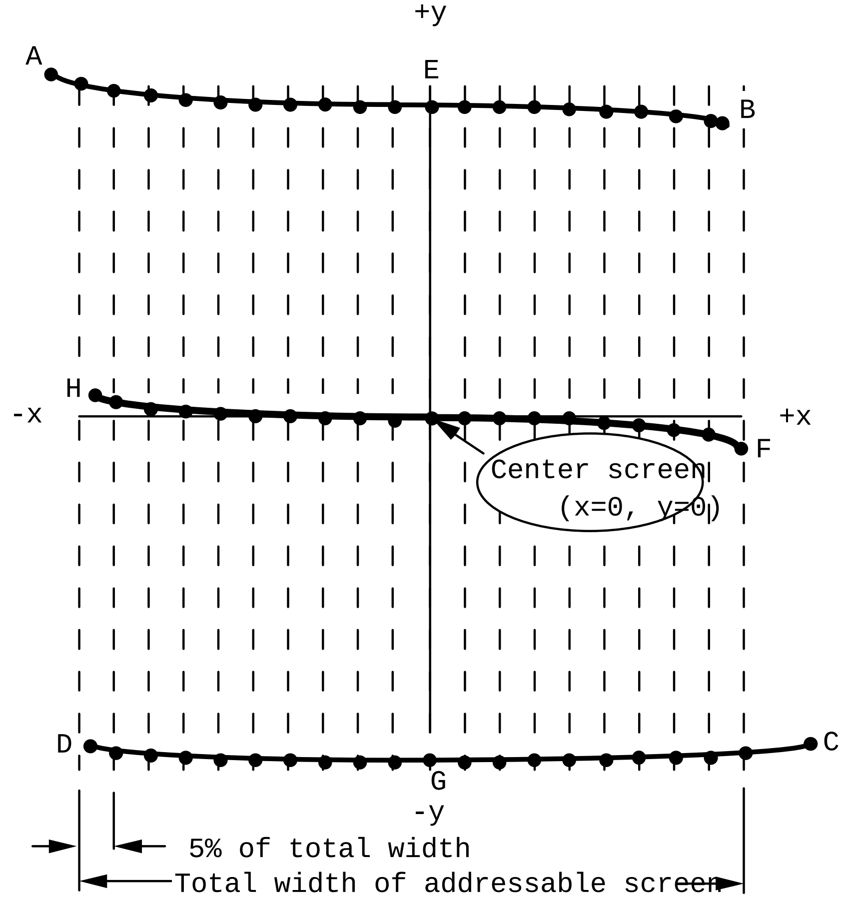


Figure II.15-2 Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates along the length of a nominally straight line. Measure x,y coordinates at 5% addressable screen intervals along the line. Position vertical lines in video to land at each of three (3) horizontal screen locations for determining waviness in the horizontal direction. Similarly, position horizontal lines in video to land at each of three (3) vertical screen locations for determining waviness in the vertical direction.

Data: Tabulate x,y positions at 5% addressable screen increments along nominally straight lines at top and bottom, major and minor axes, and left and right sides of the screen as shown in Table II.15-I. Figure II.15-3 shows the results in graphical form.

Table II.15-1. Straightness
Tabulated x,y positions at 5% addressable screen increments along nominally straight lines.

Top		Bottom		Major		Minor		Left Side		Right Side	
x	y	x	y	x	y	x	y	x	y	x	y
-6.860	6.782	-6.860	-6.853	-6.860	-0.006	-0.004	6.802	-6.986	6.802	6.858	6.802
-6.174	6.793	-6.174	-6.850	-6.174	-0.002	-0.004	6.122	-6.970	6.122	6.869	6.122
-5.488	6.804	-5.488	-6.846	-5.488	0.000	-0.008	5.442	-6.975	5.442	6.874	5.442
-4.802	6.806	-4.802	-6.846	-4.802	0.001	-0.011	4.761	-6.975	4.761	6.879	4.761
-4.116	6.807	-4.116	-6.843	-4.116	0.001	-0.011	4.081	-6.966	4.081	6.879	4.081
-3.430	6.805	-3.430	-6.840	-3.430	0.001	-0.009	3.401	-6.952	3.401	6.879	3.401
-2.744	6.802	-2.744	-6.838	-2.744	0.001	-0.008	2.721	-6.941	2.721	6.878	2.721
-2.058	6.798	-2.058	-6.836	-2.058	0.001	-0.005	2.041	-6.931	2.041	6.873	2.041
-1.372	6.794	-1.372	-6.836	-1.372	0.001	-0.002	1.360	-6.920	1.360	6.866	1.360
-0.686	6.791	-0.686	-6.836	-0.686	0.000	-0.001	0.680	-6.911	0.680	6.863	0.680
0.000	6.791	0.000	-6.838	0.000	0.000	0.000	0.000	-6.902	0.000	6.861	0.000
0.686	6.791	0.686	-6.841	0.686	0.000	0.001	-0.680	-6.903	-0.680	6.864	-0.680
1.372	6.792	1.372	-6.849	1.372	0.000	0.002	-1.360	-6.905	-1.360	6.866	-1.360
2.058	6.796	2.058	-6.856	2.058	0.000	0.003	-2.041	-6.910	-2.041	6.868	-2.041
2.744	6.800	2.744	-6.862	2.744	0.000	0.004	-2.721	-6.918	-2.721	6.871	-2.721
3.430	6.803	3.430	-6.869	3.430	0.000	0.007	-3.401	-6.923	-3.401	6.874	-3.401
4.116	6.808	4.116	-6.874	4.116	0.000	0.008	-4.081	-6.932	-4.081	6.875	-4.081
4.802	6.809	4.802	-6.877	4.802	-0.002	0.011	-4.761	-6.941	-4.761	6.876	-4.761
5.488	6.807	5.488	-6.877	5.488	-0.002	0.014	-5.442	-6.947	-5.442	6.874	-5.442
6.174	6.798	6.174	-6.873	6.174	-0.004	0.015	-6.122	-6.951	-6.122	6.866	-6.122
6.860	6.783	6.860	-6.862	6.860	-0.003	0.017	-6.802	-6.953	-6.802	6.858	-6.802

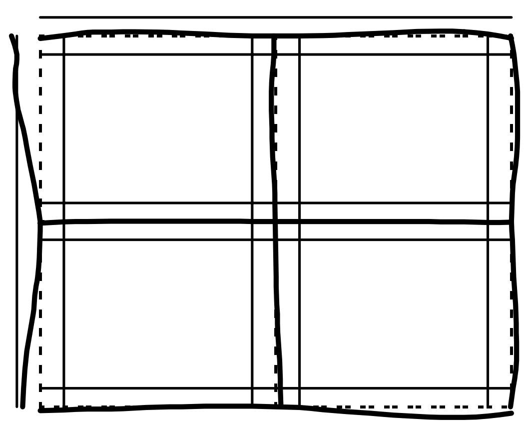


Figure II.15-3 Waviness of Orwin 1988 Monochrome monitor in 1408 x 1408 mode. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

II.16. Refresh Rate

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.16, p 9.

Vertical refresh rate for the1408 x 1408 format was set to 72.9 Hz.
Vertical refresh rate for the 1024 x 1024 stereo format was set to 120 Hz.

Objective: Define vertical and horizontal refresh rates.

Equipment: Programmable video signal generator.

Procedure: The refresh rates were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible.

Data: Report refresh rates in Hz.

Table II.16-1 Refresh Rates as Tested

	Monoscopic Mode	Stereo Mode
Addressability	1408 x 1408	1024 x 1024
Vertical Scan Horizontal Scan	72.9 Hz kHz	120 Hz kHz

II.17. Extinction Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.17, p10.

Stereo extinction ratio was averaged 32.1 to 1 (40.9 left, 23.2 right) at screen center. Luminance of white varied by up to 7.3% across the screen. Chromaticity variations of white were less than 0.005 delta u'v' units.

Objective: Measure stereo extinction ratio

Equipment: Two “stereo” pairs with full addressability. One pair has left center at command level of 255 (or Cmax) and right center at 0. The other pair has right center at command level of 255 (or Cmax) and left center at 0.

Stereoscopic-mode measurements were made using a commercially-available Nuvision 19-inch LCD shutter with passive polarized eyeglasses.

Procedure: Calibrate monitor to 0.1 fL Lmin and 35 fL Lmax (no ambient). Measure ratio of Lmax to Lmin on both left and right side images through the stereo system.

Data: Extinction ratio (left) = L (left,on, white/black)/left,off, black/white)

L(left,on, white/black) ~ trans(left,on)*trans(stereo)*L(max)*Duty(left)
+ trans(left,off)*trans (stereo)*L(min)*Duty (right)
Use left,off/right,on to perform this measurement

Extinction ratio (right) = L (right,on,white/black)/right,off, black/white)

L(right,on, white/black) ~
trans(right,on)*trans(stereo)*L(max)*Duty(right)
+ trans(right,off)*trans (stereo)*L(min)*Duty (left)
Use left,on/right,off to perform this measurement

Stereo extinction ratio is average of left and right ratios defined above.

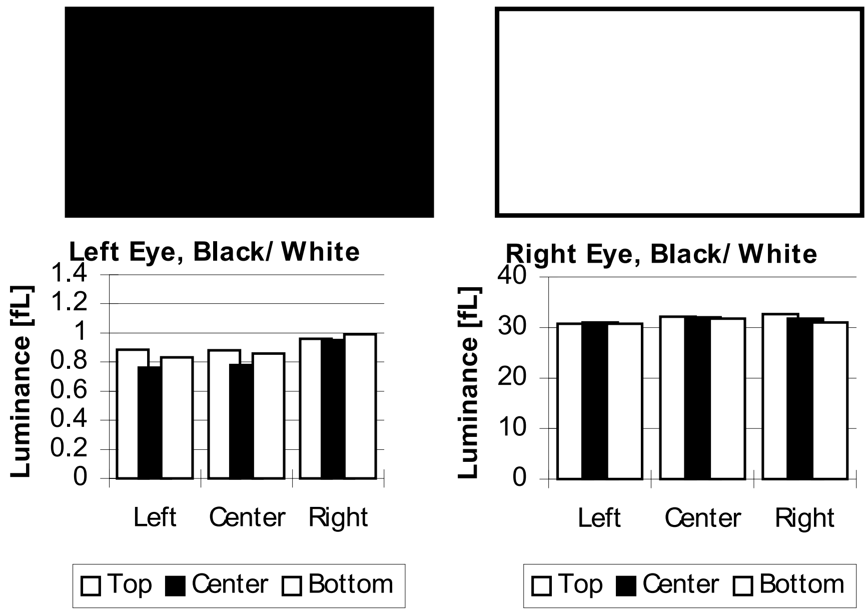


Fig.II.17-1. Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.

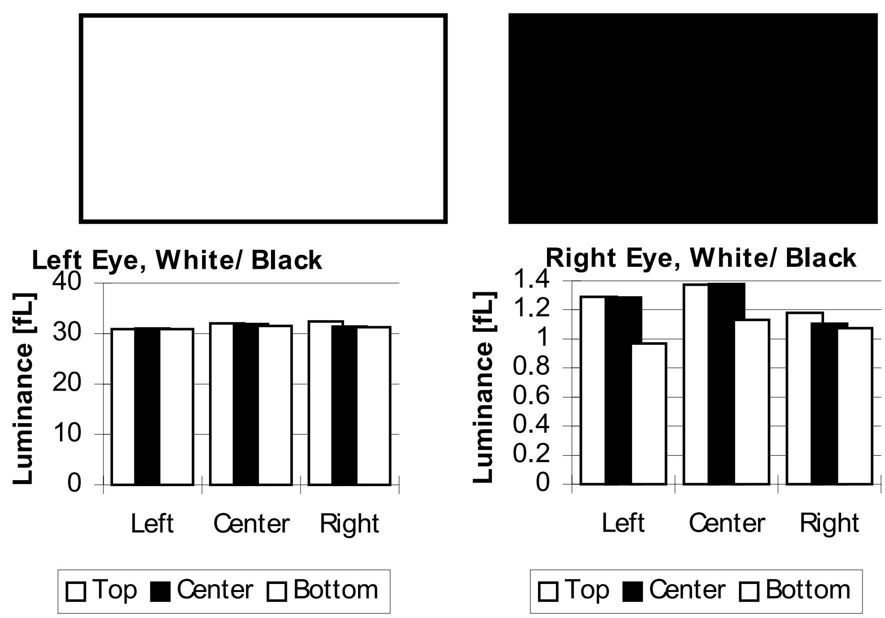


Fig.II.17-2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.

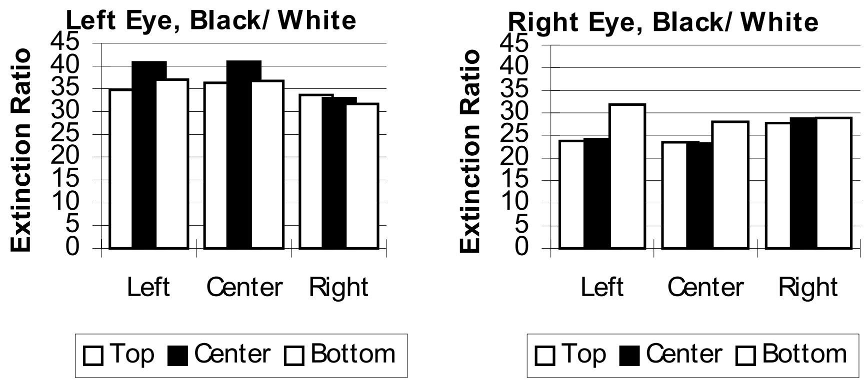


Fig.II.17-3. Spatial Uniformity of extinction ratio in stereo mode.

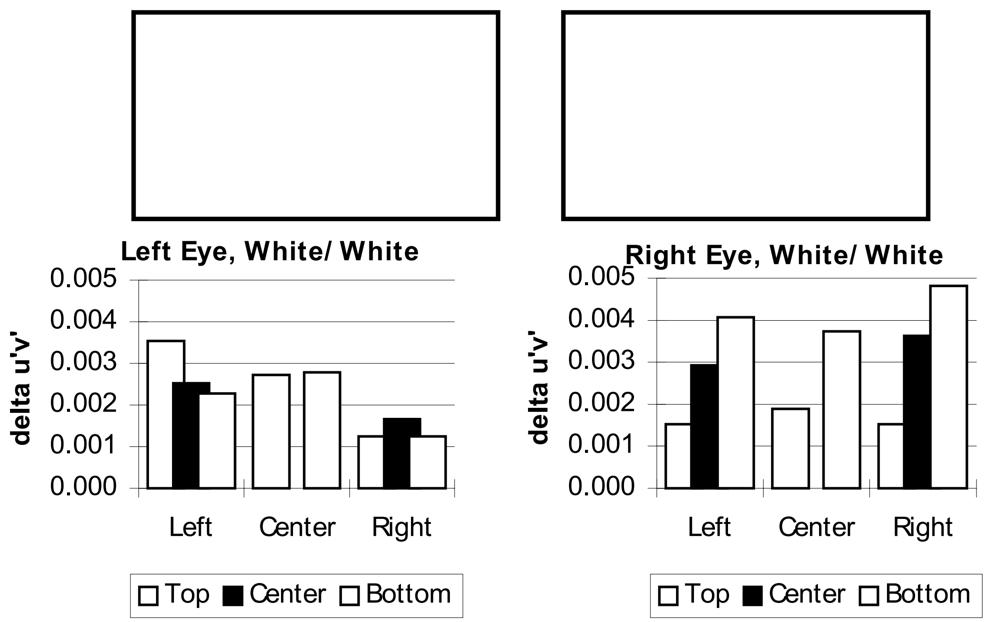


Fig.II.17-4 Spatial Uniformity of chromaticity of white in stereo mode.

II.18. Linearity

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.2, page 73.

The maximum nonlinearity of the scan was 0.73% of full screen.

Objective: Measure the relation between the actual position of a pixel on the screen and the commanded position to quantify effects of raster nonlinearity. Nonlinearity of scan degrades the preservation of scale in images across the display.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use grille patterns of single-pixel horizontal lines and single-pixel vertical lines displayed at 100% L_{max}. Lines are equally spaced in addressable pixels. Spacing must be constant and equal to approximately 5% screen width and height to the nearest addressable pixel as shown in Figure II.18-1.

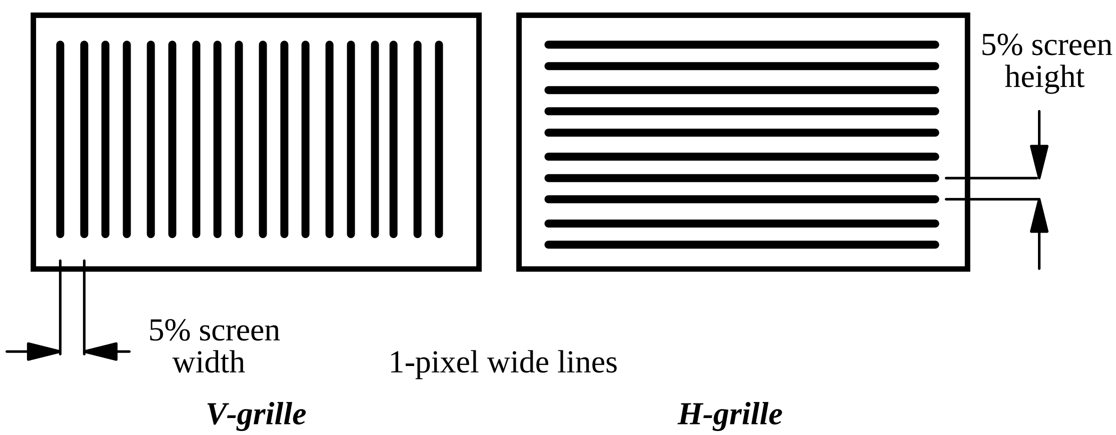


Figure II.18-1. *Grille patterns for measuring linearity*

Procedure: The linearity of the raster scan is determined by measuring the positions of lines on the screen. Vertical lines are measured for the horizontal scan, and horizontal lines for the vertical scan. Lines are commanded to 100% Lmax and are equally spaced in the time domain by pixel indexing on the video test pattern. Use optic module to locate center of line profiles in conjunction with x,y-translation stage to measure screen x,y coordinates of points where video pattern vertical lines intersect horizontal centerline of screen and where horizontal lines intersect vertical centerline of the CRT screen as shown in Figure II.18-2.

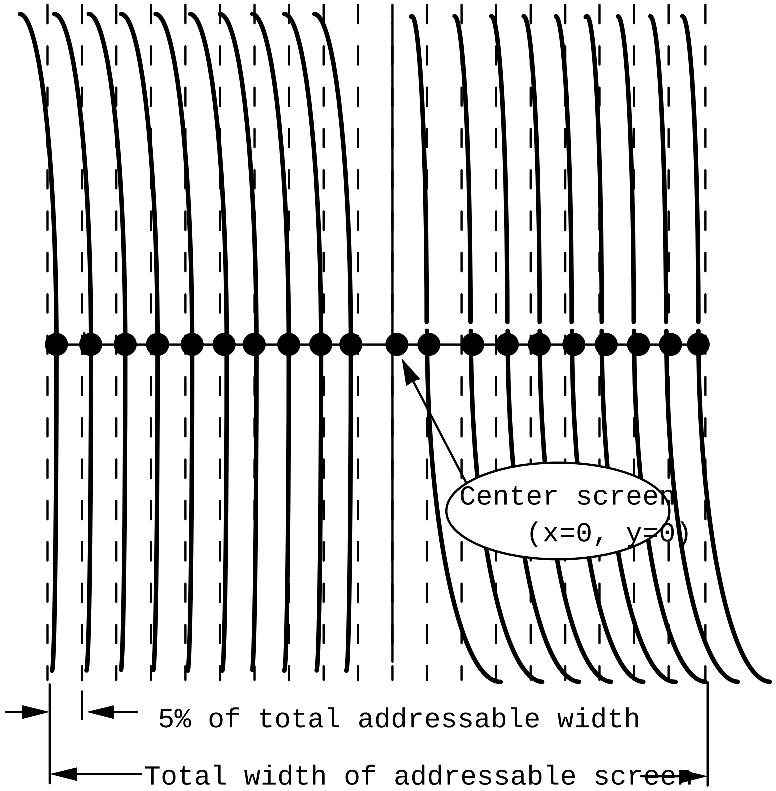


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

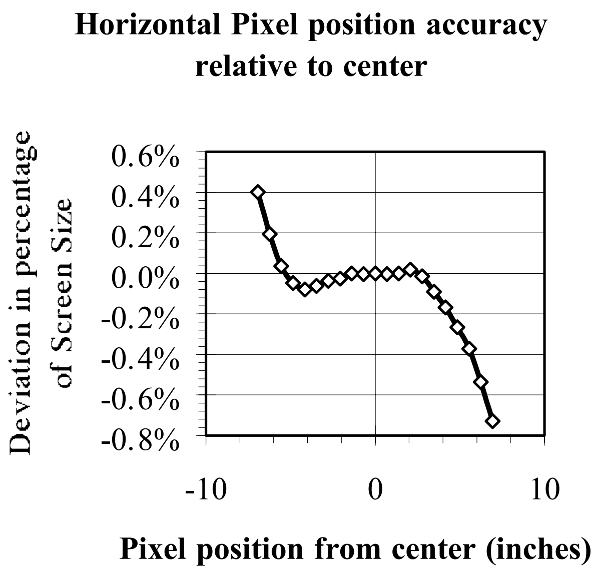
Data: Tabulate x,y positions of equally spaced lines (nominally 5% addressable screen apart) along major (horizontal centerline) and minor (vertical centerline) axes of the raster. If both scans were truly linear, the differences in the positions of adjacent lines would be a constant. The departures of these differences from constancy impacts the absolute position of each pixel on the screen and is, then, the nonlinearity. The degree of nonlinearity may be different between left and right and between top and bottom. The maximum horizontal and vertical nonlinearities (referred to full screen size) are listed in table II.18-1. The complete measured data are listed in table II.18-2 and shown graphically in Figure II.18-3.

Table II.18-1. Maximum Horizontal and Vertical Nonlinearities

Format	Left Side	Right Side	Top	Bottom
1408 x 1408	0.40%	0.73%	0.44%	0.08%

Table II.18-2. Horizontal and Vertical Nonlinearities Data

Vertical Lines x-Position (mils)		Horizontal lines y-Position (mils)	
Left Side	**Right Side**	**Top**	**Bottom**
-6880	6835	6840	-6791
-6215	6168	6154	-6104
-5543	5497	5468	-5423
-4861	4818	4780	-4745
-4172	4138	4092	-4063
-3476	3455	3405	-3383
-2779	2772	2722	-2706
-2084	2083	2038	-2029
-1387	1387	1360	-1354
-694	693	679	-677
0	0	0	0



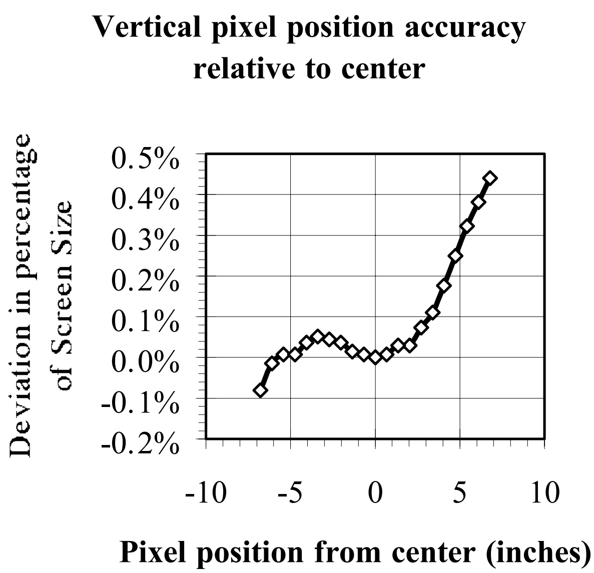


Fig. II.18-5 Horizontal and vertical linearity characteristics.

II.19. Jitter/Swim/Drift

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

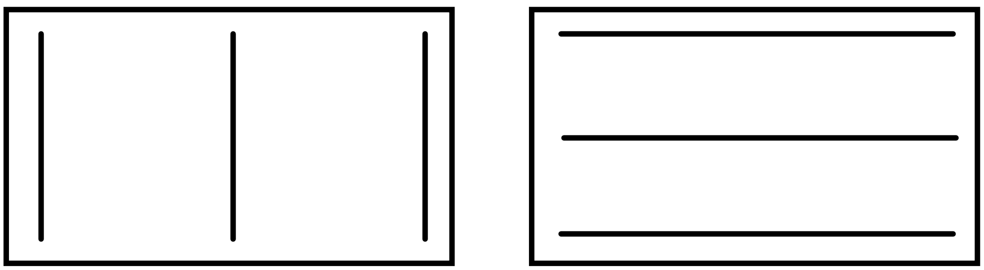
Maximum jitter and swim/drift was 1.94 mils and 2.29 mils, respectively.

Objective: Measure amplitude and frequency of variations in beam spot position of the CRT display. Quantify the effects of perceptible time varying raster distortions: jitter, swim, and drift. The perceptibility of changes in the

position of an image depends upon the amplitude and frequency of the motions, which can be caused by imprecise control electronics or external magnetic fields.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.19-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



V-grille for measuring horizontal motion H-grille for measuring vertical motion

1-pixel wide lines

Three-line grille test patterns.
Figure II.19-1

Procedure: With the monitor set up for intended scanning rates, measure vertical and horizontal line jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration as displayed using grille video test patterns. Generate a histogram of raster variance with time. The measurement interval must be equal to a single field period.

Optionally, for multi-sync monitors measure jitter over the specified range of scanning rates. Some monitors running vertical scan rates other than AC line frequency may exhibit increased jitter.

Measure and report instrumentation motion by viewing Ronchi ruling or illuminated razor edge mounted to the top of the display. It may be necessary to mount both the optics and the monitor on a vibration damped surface to reduce vibrations.

Data: Tabulate motion as a function of time in x-direction at top-left corner screen location. Repeat for variance in y-direction. Tabulate maximum motions (in mils) with display input count level corresponding to L_{max} for jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration. The data are presented in Table II.19-

1. Both the monitor and the Microvision equipment sit on a vibration-damped aluminum-slab measurement bench. The motion of the test bench was a factor of 10 times smaller than the CRT raster motion.

Table II.19-1. Jitter/Swim/Drift

Time scales: Jitter 2 sec., Swim 10 sec., and Drift 60 sec.

		H-lines	V-lines	maximums
10D corner	Max Motions			
	Jitter	0.719	2.01	
	Swim	0.96	2.30	
	Drift	1.01	2.42	
Black Tape	Max Motions			
	Jitter	0.081	0.071	
	Swim	0.116	0.086	
	Drift	0.131	0.132	
Less Tape Motion				
	Jitter	0.64	1.94	1.94
	Swim	0.84	2.21	2.21
	Drift	0.88	2.29	2.29

II.20 Warmup Period

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.20, p. 10.

A 49 minute warm-up was necessary for luminance stability of Lmin = 0.12 fL +/- 10%.

Objective: Define warm-up period

Equipment: Photometer, test target (full screen 0 count)

Procedure: Turn monitor off for three-hour period. Turn monitor on and measure center of screen luminance (Lmin as defined in Dynamic range measurement) at 1-minute intervals for first five minutes and five minute intervals thereafter. Discontinue when three successive measurements are ± 10% of Lmin.

Data: Pass if Lmin within ± 50% in 30 minutes and ±10% in 60 minutes.

The luminance of the screen (commanded to the minimum input level, 0 for Lmin) was monitored for 120 minutes after a cold start. Measurements were taken every minute. Figure II.20-1 shows the data for 1280 x 1024 format in graphical form. The luminance remains very stable after 49 minutes.

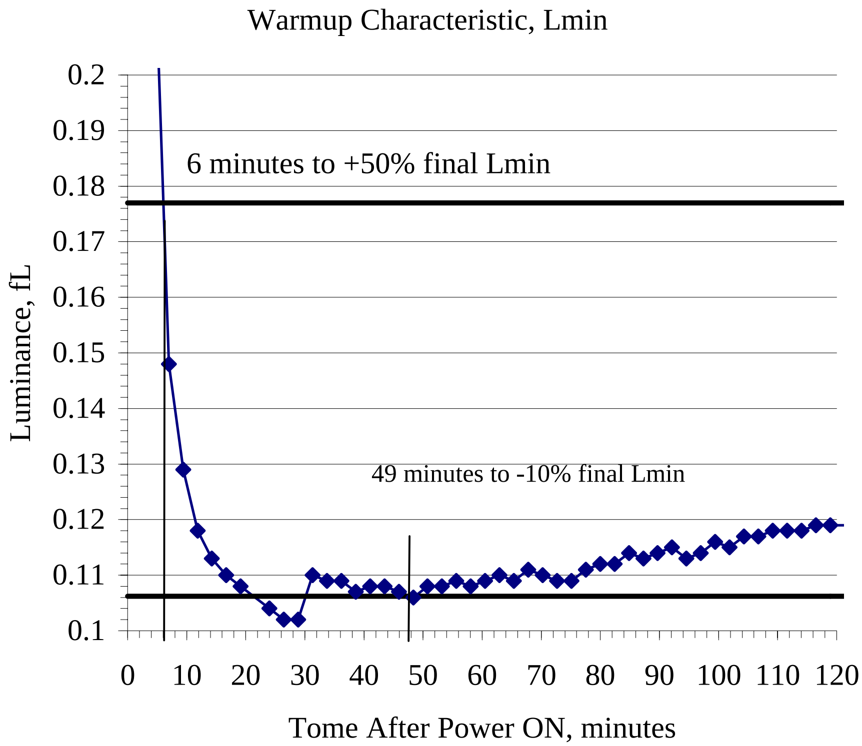


Figure II.20.1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0. (Note suppressed zero on luminance scale).